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EP 0464599 A1 EP 0347666 A2 JP 070158689 A
JP 050126200 A US 5738343 A US 5333455 A

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(54) Abstract Title
Vibration damping

(57) A resilient mount (12) for resiliently supporting a member on a body, comprising body fixing means (16) for fixing the mount to the body, member fixing means (18) for fixing the mount to the member, resilient interconnection means (10) resiliently interconnecting the body fixing means (16) and the member fixing means (18) for flexing in response to vibration of the member relative to the body, the resilient interconnection means (10) at least partially defining a fluid-filled working chamber (14), the mount further including an amplification chamber and a quantity of piezoelectric material (26) operable to control the volume of the amplification chamber and electrical control means (36) coupled to the piezoelectric material (26) and arranged to cause the piezoelectric material (26) to control the volume of the amplification chamber in relation to the frequency of the said vibration and thereby to generate a force between the body fixing means and the member fixing means.

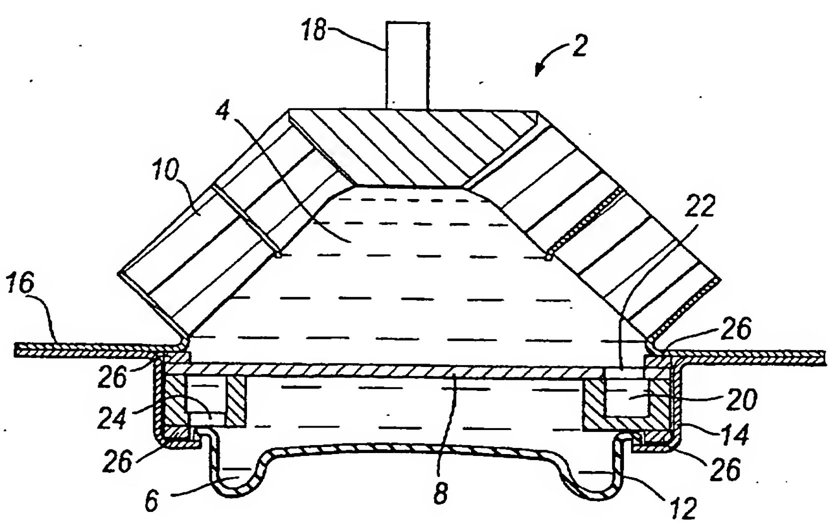

Fig. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977.

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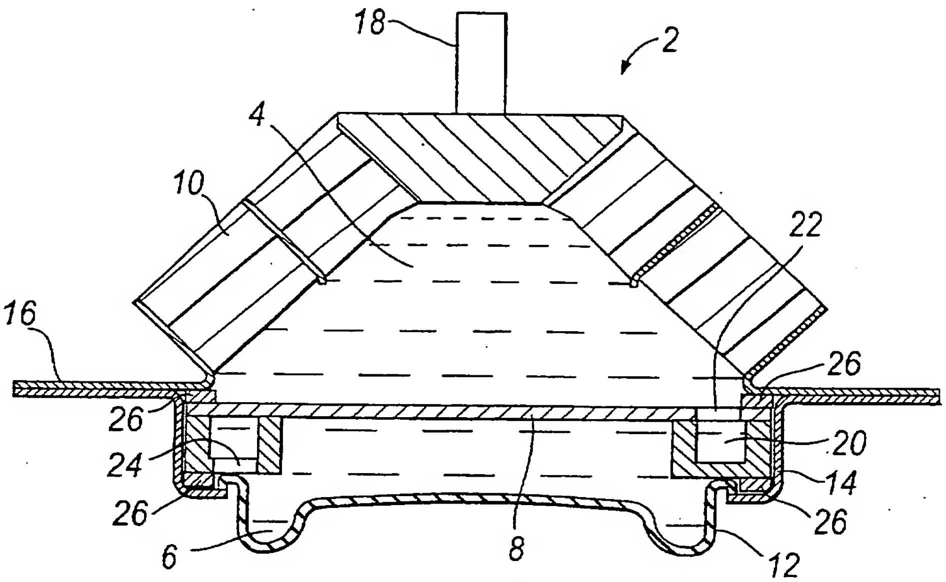

Fig.1

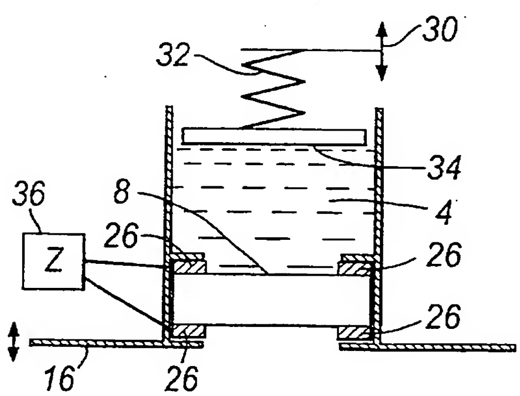

Fig.2

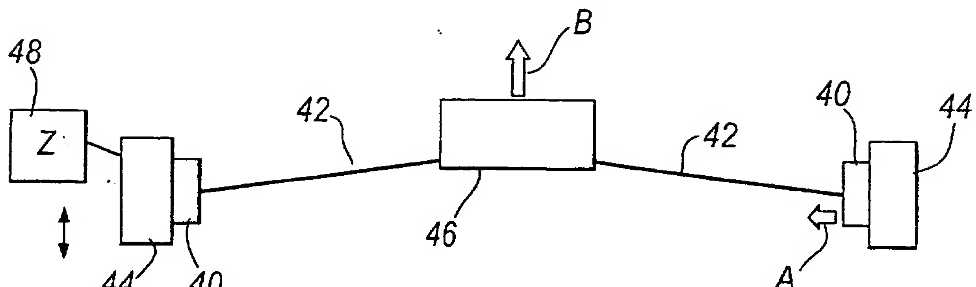

Fig.3

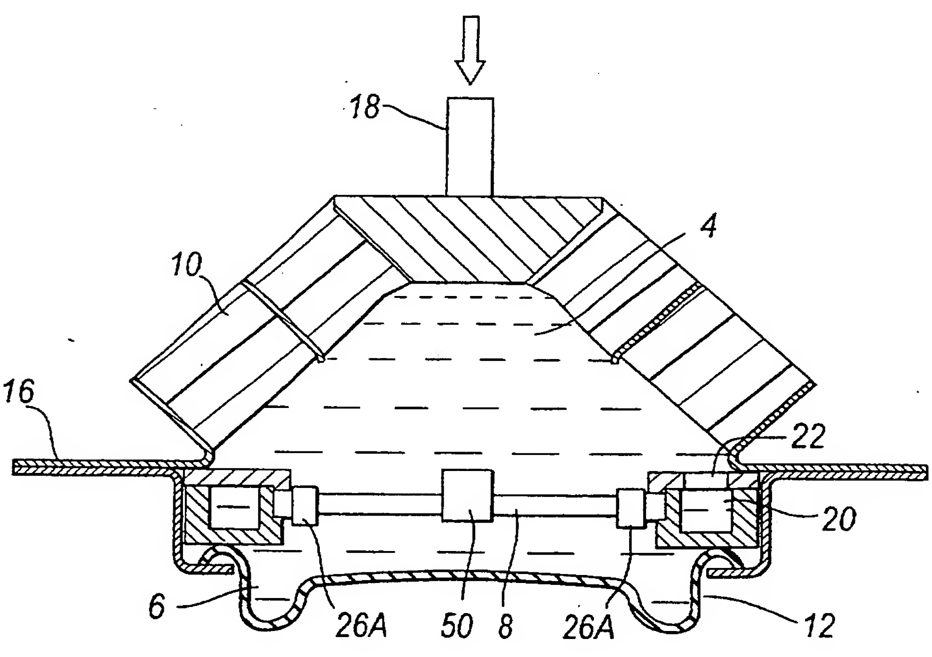

Fig.4

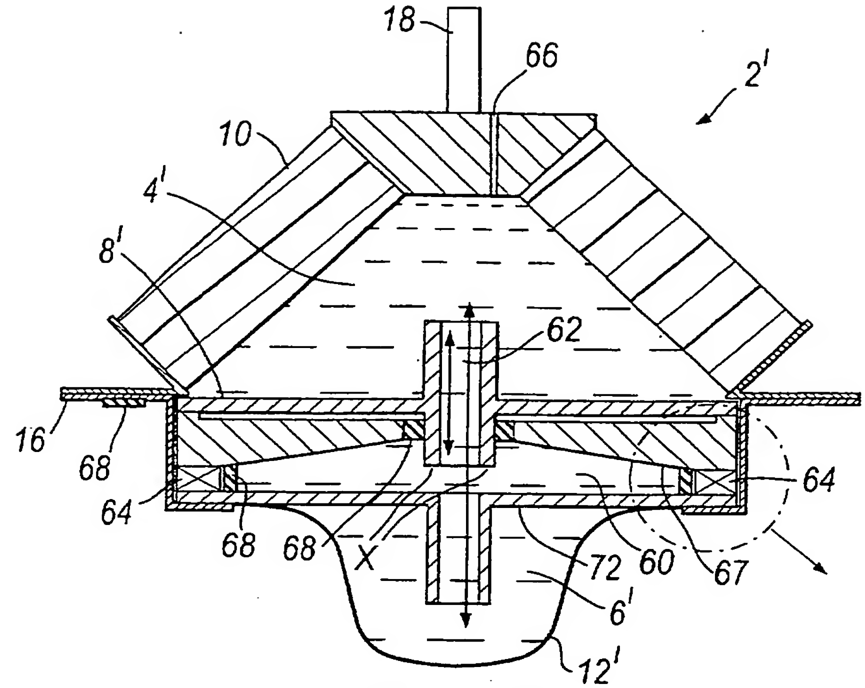

Fig.5A

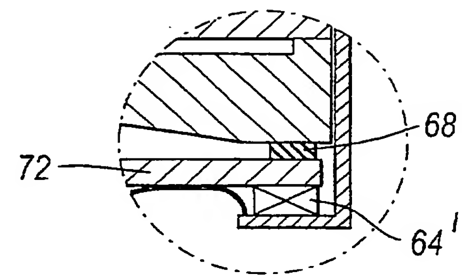

Fig.5B

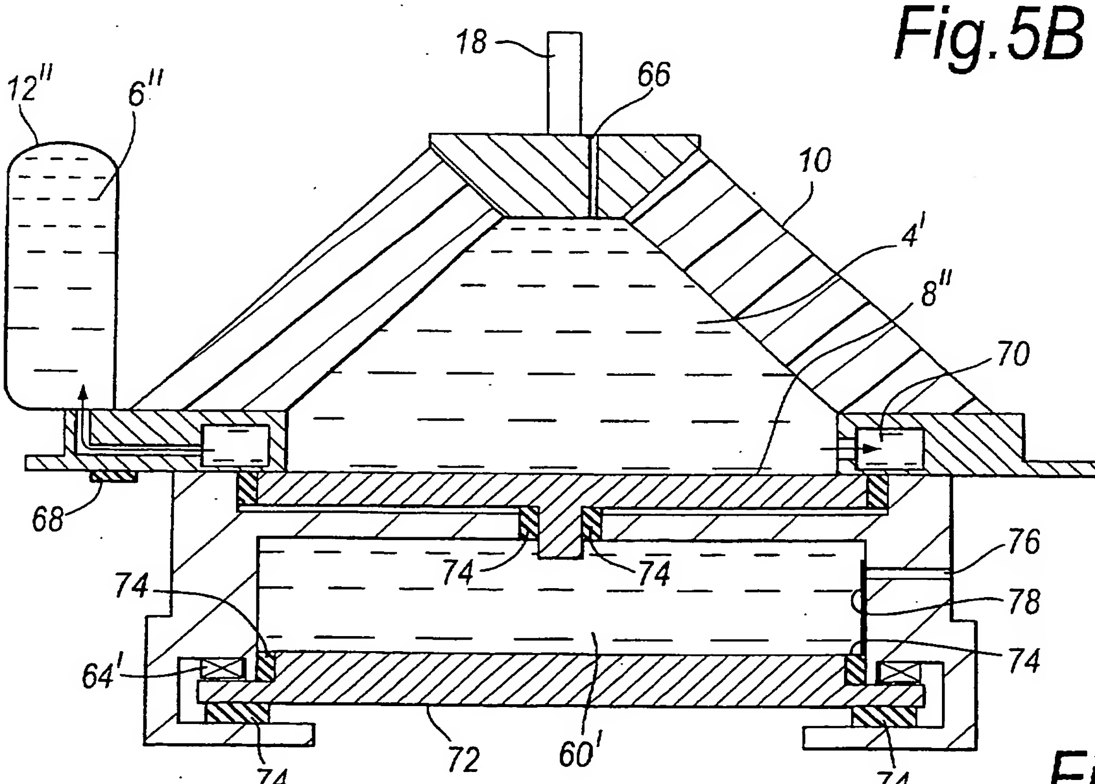

Fig.6

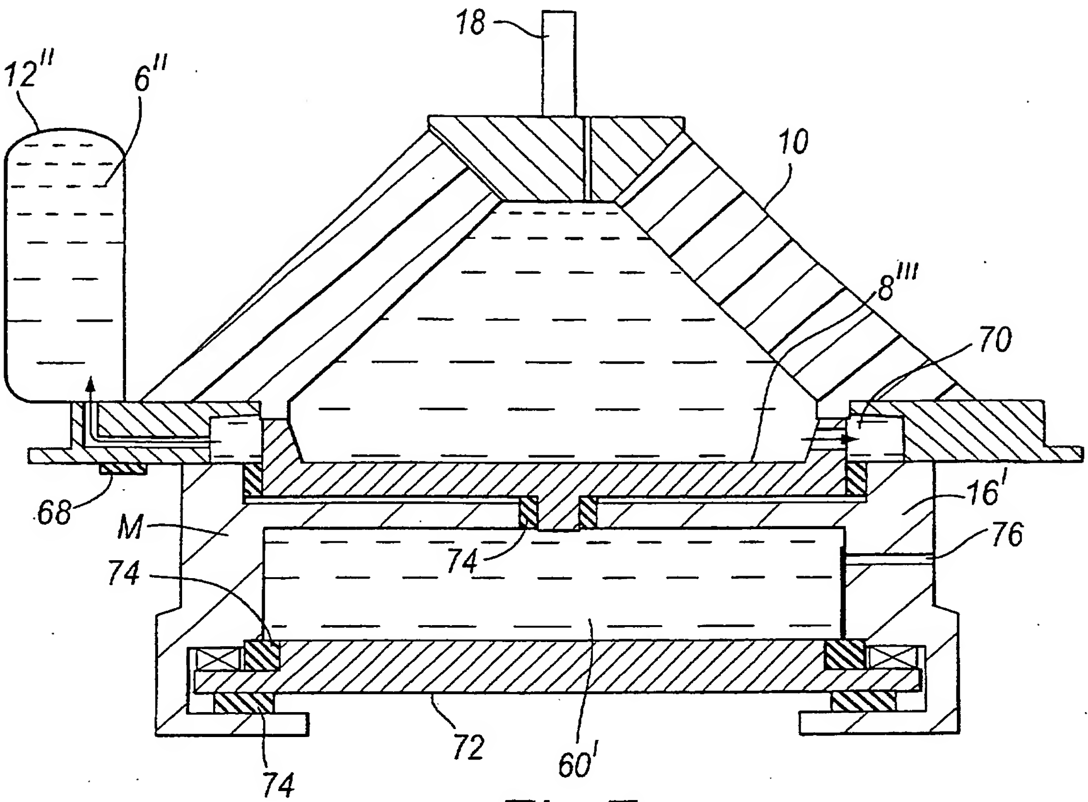

Fig.7

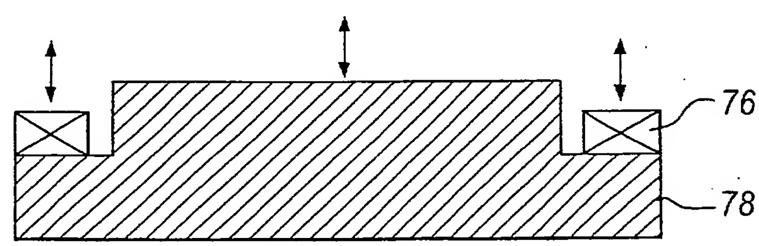

Fig.8A

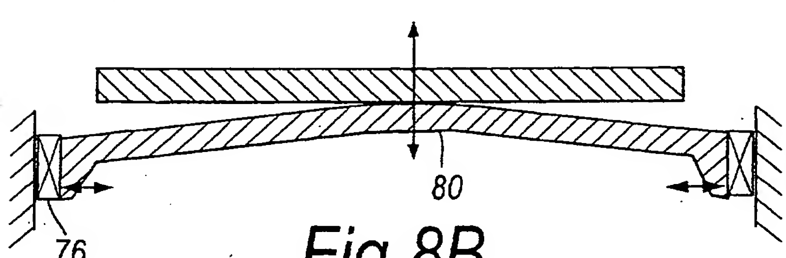

Fig.8B

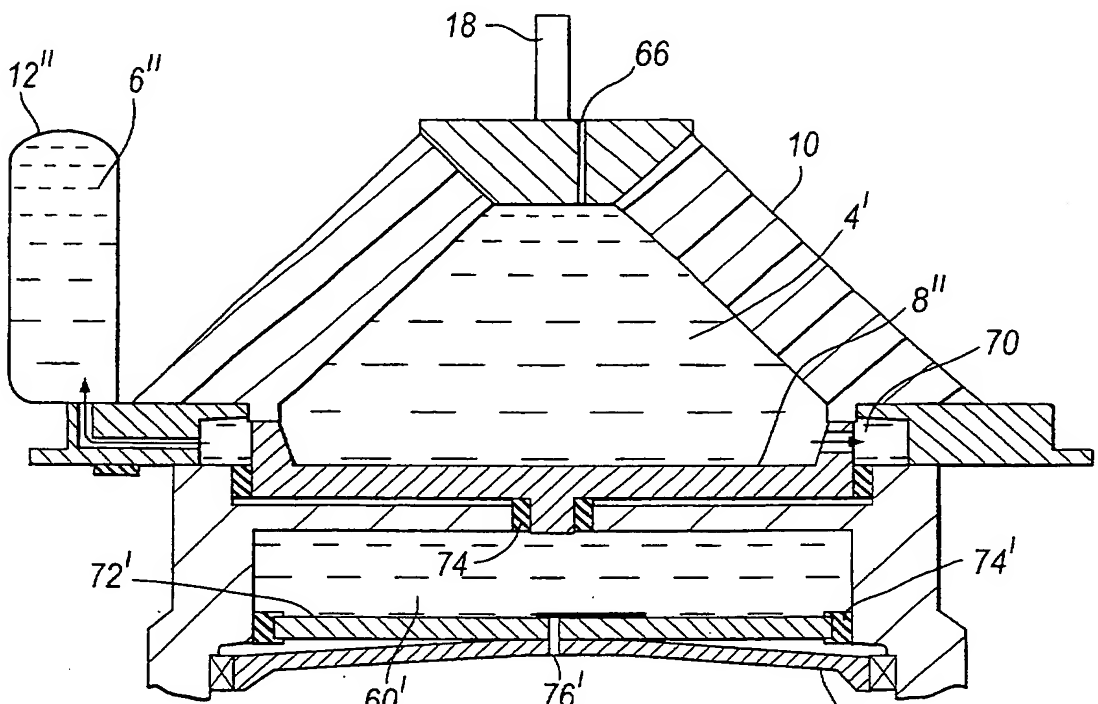

Fig.9

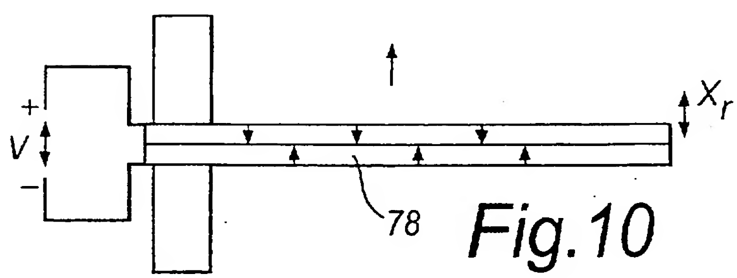

Fig.10

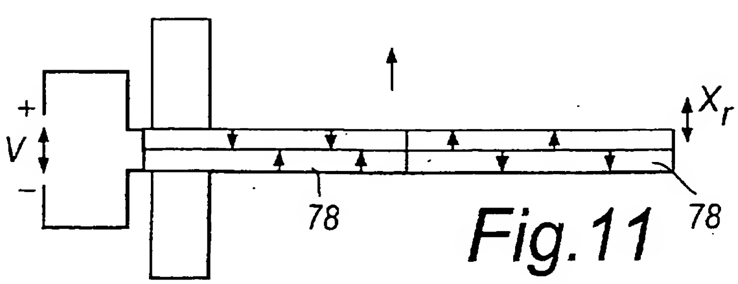

Fig.11

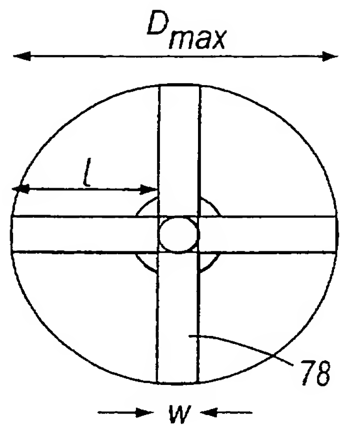

Fig.12A

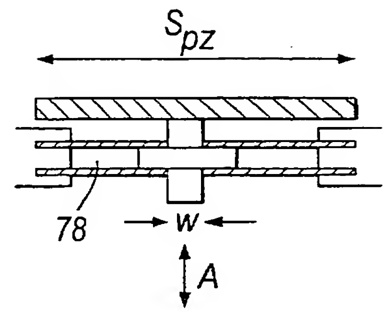

Fig.12B

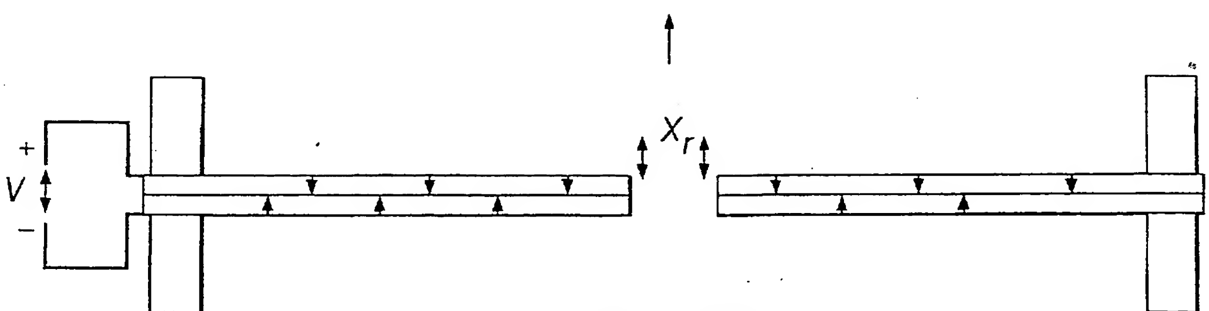

Fig.13

VIBRATION DAMPING

This invention relates to a resilient engine mount and to a damper for damping a vibrating object.

According to a first aspect of the invention, a resilient mount for resiliently supporting a member on a body, comprises body fixing means for fixing the mount to the body, member fixing means for fixing the mount to the member, resilient interconnection means resiliently interconnecting the body fixing means and the member fixing means for flexing in response to vibration of the member relative to the body, the resilient interconnection means at least partially defining a fluid-filled working chamber, the mount further including a fluid-filled amplification chamber and a quantity of piezoelectric material operable to control the volume of the amplification chamber and electrical control means coupled to the piezoelectric material and arranged to cause the piezoelectric material to control the volume of the amplification chamber in relation to the frequency of the said vibration and thereby to generate a force between the body fixing means and the member fixing means.

According to a second aspect of the invention there is provided a damper for damping a vibrating object comprising a damping mass, fixing means for fixing the damper to the vibrating object and a quantity of piezoelectric material arranged to couple the damping mass to the fixing means.

An object of the invention is to reduce the transmission of vibrations by producing contra-vibrations using a piezoelectric element.

Embodiments of an engine mount and a damper in accordance with the invention will now be described by way of example with reference to the drawings in which:-

Figure 1 is a schematic cross-sectional view of an engine mount;

Figure 2 is a simplified schematic view of the mount of Figure 1;

Figure 3 is a schematic view of a damper;

Figure 4 is a schematic cross-sectional view of an alternative engine mount;

Figure 5A is a schematic cross-sectional view of an alternative engine mount including a piezoelectric, hydraulic amplifier;

Figure 5B is an enlargement of part of Figure 5A showing an alternative arrangement;

Figure 6 is a schematic cross-sectional view of a further alternative engine mount having an external compensation chamber and a pressurized amplification chamber;

Figure 7 is a schematic cross-sectional view of a modified form of the engine mount of Figure 6;

Figure 8A is a schematic diagram showing piezoelectric-induced movement;

Figure 8B is a schematic diagram showing an alternative form of piezoelectric-induced movement;

Figure 9 is a schematic cross-sectional view of a further modified form of the engine mount of Figures 6 and 7;

Figure 10 is a schematic diagram of a bimorph piezoelectric element;

Figure 11 is a schematic diagram of a modified form of the bimorph element of Figure 10;

Figure 12A is a plan view of bimorph elements of the form of Figures 10 and 11 arranged in a cross;

Figure 12B is a cross-sectional view of the arrangement of Figure 12A; and

Figure 13 is a schematic cross-sectional view of an annulus of bimorph piezoelectric

material.

With reference to Figure 1, a hydroelastic engine mount 2 has a working chamber 4 and a compensation chamber 6. The chambers are filled with hydraulic fluid and separated by a wall 8. The working chamber 4 is substantially defined by an elastomeric arch 10 and a first side of the wall 8. The compensation chamber is substantially defined by a flexible membrane 12, the second side of the wall 8 and a generally rigid extension 14 of a fixing armature 16. The fixing armature 16 is used to fix the mount 2 to a vehicle body.

At the top of the arch 10, an upper insert 18 is provided for fixing the mount to a vehicle engine.

A peripheral hydraulic conduit 20 is located generally adjacent extension 14 and provides a flow-restricted interconnection between the main and compensation chambers 4 and 6. The conduit 20 opens into the working chamber via opening 22 and correspondingly, the conduit 20 opens into the compensation chamber 6 via opening 24.

The wall 8 and conduit 20 are mounted to the armature 16 and extension 14 via blocks of piezoelectric material 26. Thus the wall 8 and conduit 20 are effectively decoupled from the remainder of the mount 2 by the blocks of piezoelectric material.

The operation of the mount 2 will now be described with reference to the simplified form

of the mount shown in Figure 2. Vibrations of the engine cause resilient flexing of the material of the arch 10 and consequent pressure fluctuations in the hydraulic fluid. It is assumed that at low frequency engine vibrations, the engine mount achieves damping at least in part by the movement of the mass of the fluid between the two chambers 4 and 6 via the conduit 20. Since the pressure changes cannot be accommodated by flow through the conduit at high frequencies, these high frequency vibrations are passed to the vehicle body via the wall 8.

This situation is shown in Figure 2. In this figure, the vertical component of the resilience of the arch 10 is represented by a schematic spring 32 and the effective surface area of the arch 10 is represented by a piston 34. Engine vibrations 30 are passed via the elastomeric arch 10 (represented by schematic spring 32 and piston 34) to the fluid of main chamber 4 via the effective surface area 34 of the arch 10. The conduit 20 is omitted in Figure 2 since at high frequencies this conduit is effectively blocked. Thus, movement of the surface 34 is transmitted to the flexible wall 8 and then to the armature 16 via piezoelectric blocks 26.

Advantageously, the transmission of these high frequency vibrations may be reduced using the piezoelectric blocks 26 in one or both of two modes.

Firstly, a control circuit 36 may be used to energise the piezoelectric blocks 26 to cause movement of the wall 8 relative to the armature 16 and thereby to dampen the higher

frequency vibrations rather than allow them to be transmitted to the vehicle body via the armature 16. The circuit 36 may energise the blocks 26 in response, for example to engine speed or sensed vibration.

The damping effect is achieved by using the piezoelectric blocks 26 to make small variations in the volume of the working chamber 4. These small variations result from movement of the wall 8 caused by movement of the piezoelectric blocks 26. Thus even though fluid cannot pass in significant amounts through the conduit 20, the piezoelectric blocks can be used instead to control pressure fluctuations in the working chamber 4 and thereby to control vibration transmission from the upper insert 18 to the armature 16. This is possible in part, because the high frequency vibrations are generally of low amplitude relative to those at low frequency vibrations. Thus the dimensional changes in the piezoelectric blocks 26 need not be large to be able to accommodate the vibration amplitude at higher frequencies.

In the second mode, the vibrations transmitted through the piezoelectric blocks 26 will generate electrical energy in the piezoelectric blocks 26 which can be dissipated. In other words, the vibrational energy in the wall 8 can be converted into electrical energy by the piezoelectric blocks 26. Dissipation of that energy in an electrical load allows the wall 8 to do work on the load which has the effect of damping movement of the wall 8 and reducing the vibrational energy which is transmitted to the vehicle body via the armature 16.

With reference to Figure 3, blocks of piezoelectric material 40 are used to couple generally rigid suspension arms 42 to a vibrating structure 44. The arms 42 are interconnected via a damping mass 46. The arms 42 are arranged so that expansion or contraction of the piezoelectric elements generally along the direction of arrow A causes movement of the damping mass 46 generally along the direction of arrow B.

The arms 42 are arranged to have a small deflection (upwardly in Figure 3) even when the piezoelectric elements 40 are not energised. This ensures that the mass 46 moves in a predetermined direction when the elements 40 are energised.

The piezoelectric elements 40 are connected to an electrical control circuit 48 which is operable to produce controlled changes of the dimension of the piezoelectric elements 40 along the direction of arrow A. In this way, the control circuit 48 is able to induce movement of the damping mass 46 along the direction of arrow B. By arranging for movement of the damping mass 46 to be generally in antiphase with the vibrations of the vibrating structure 44, a damping effect is achieved.

If ΔL is the change in dimension of each piezoelectric element along the direction of arrow A, X is the displacement of damping mass 46 along the direction of arrow B and L_o is the initial length of each arm then the displacement X as a function of ΔL is:-

$$X = L_o \Delta L$$

For example, if ΔL is 0.01mm and L_o is 30mm, X is a few tenths of a millimetre. Thus the mechanical arrangement with these parameters provides an amplification of the displacement of the piezoelectric elements by a factor greater than 10. For the amplification effect, it is important that the arms 42 are inextensible. Thus they efficiently transmit displacement from the piezoelectric elements 40 to the damping mass 46. However, resonance of the arms will have an effect on the amplification factor. Furthermore, it will be appreciated that in practice, since the piezoelectric elements are not infinitely stiff in the shear direction, some movement of the ends of the arms 42 will occur in that direction. However, it will be apparent to those skilled in the art that despite such practical limitations, the arrangement described above provides an effective and easily controllable inertial damper.

The arrangement of Figure 3 can be extended in different directions, for example into the plane of the Figure, in order to allow controlled movement of the damping mass in other directions.

This principle of amplifying the movement of a mass in a dynamic damper can be applied, for example, to a hydroelastic engine mount as described below in connection with Figures 4 and 9.

With reference to Figure 4, by positioning piezoelectric elements 26A around the periphery of the wall 8 just on the inside of the conduit 20 and by ensuring that the wall

8 is made from an inextensible and flexible membrane, an arrangement similar to that shown in Figure 3 is produced. In this case, the wall 8 is equivalent to the arms 42 of Figure 3 and the mass of the fluid in the chamber 4 is equivalent to the dynamic mass 46 of Figure 3.

An additional mass 50 may also be used. This mass may typically be located centrally in the wall 8.

This arrangement provides improved damping vibrations particularly at very low frequencies. Thus this arrangement is particularly suitable for damping the type of vibrations found at engine idle speeds since the displacement of the damping mass can be of the order of a few tenths of millimetre which is of the same order as the amplitude of the excitation produced by an idling engine.

With reference to Figure 5A, an alternative mount 2' has a working chamber 4', a compensation chamber 6' enclosed in a flexible membrane 12', and a third, amplification chamber 60.

The working chamber, amplification chamber and compensation chamber are all interconnected by a low frequency passage 62 which passes vertically and generally centrally through the three chambers. The low frequency canal opens into the compensation chamber 6' and 4' and has an opening also into the amplification chamber

60.

Within the amplification chamber 60, piezoelectric element 64 (which is preferably in the form of an annulus) is operable to cause vibrations of a lower wall 72 which divides the amplification chamber 60 from the compensation chamber 6'. This generates pressure changes in the amplification chamber 60 which at high frequencies causes movement of the dividing wall 8' by application of pressure at point X. It will be noted that the area of the wall 72 is much greater than the area at point X. This therefore amplifies the amplitude of the movement of the piezoelectric elements 64.

In operation, at high frequencies fluid substantially does not pass along the low frequency canal 62. By applying an electric field to the piezoelectric annulus 64, it is possible to generate contra-vibrations which attenuate the vibrations which are transmitted to the mount from an engine by the upper insert 18.

By using an external control circuit to drive the annulus 64, the dividing wall 8' may be moved generally in anti-phase or in other ways as described above in connection with the mounts of Figures 1 and 4 above.

In order to fill the mount with fluid, a filler canal 66 is provided in the upper insert 18. Since all the chambers are interconnected by the low frequency canal 62, it is only necessary to have one filling point. An inclined member 67 fixed to the wall 8', has an

inclined lower surface to direct air bubbles towards the centre of the mount so that they may pass through the low frequency canal during filling of the mount. The member 67 is sealed using seals 68.

It will be noted that the piezoelectric elements 64 may be mounted below the wall 72 or both above and below the wall 72. With reference to Figure 5B, the piezoelectric element 64' may be mounted below the wall 72 and the wall 72 sealed above using seals 68'.

Thus, the engine mount of Figure 5A requires only a single filler canal and may be filled in a single operation.

The external circuit which controls the piezoelectric elements may take as an input, a signal from a piezoelectric transducer 68 (preferably of PVDF material) in order to produce a feedback signal. The positioning of the piezoelectric transducer 68 under the armature 16 allows transmitted vibrations (which would be transmitted to the vehicle body) to be measured and/or sensed.

In the mount of Figure 5, if excessive vibrations are induced by the piezoelectric annulus 64, under dynamic conditions it is possible that the pressure of the fluid in the amplification chamber will be sufficiently reduced that it vaporises. If this is allowed to happen, the dividing wall 8' is no longer under control of the piezoelectric annulus

64. Thus there is a limit to the compensation which may be applied by the annulus 64.

To overcome this problem, in Figure 6, the amplification chamber 60' is sealed. In this embodiment, the compensation chamber 6" is coupled to the working chamber 4' by a peripheral canal 70. By arranging for the amplification chamber 60' to be sealed, it is possible to raise the pressure of the fluid in that chamber. Thus, the pressure in this chamber ($P + \Delta P$) should be greater than the saturated vapour pressure of the fluid used (where P is the static pressure and ΔP is the pressure generated by the piezoelectric annulus 64' during operation). In other respects the operation of the mount of Figure 6 is similar to that of Figure 5. Vibrations of the annulus 64' cause movement of the fluid in the compensation chamber 60' via a wall 72'. The wall 72' is sealed on flexible rubber seals 74. The pressure P can be obtained by filling the chamber 60' with fluid under pressure or by pressing the wall 72' after filling the chamber 60'. The latter may be achieved by crimping the armature 16' at M.

This arrangement, however, requires an additional filler canal 76 which may optionally be sealed automatically by a flap 78 after filling of the chamber 60', under action of the pressure within the chamber 60'.

Figure 7 shows a modification of the mount of Figure 6 in which the entrance to the peripheral canal 70 is formed in the dividing wall 8'''.

With reference to Figures 8A and 8B, it will be noted that different arrangements of the piezoelectric elements shown above may result in generally vertical mechanical movement.

For example, with reference to Figure 8A, an annulus of piezoelectric material 76 may be used to generate movement in the member 78 by causing axial changes in the dimension of the annulus 76.

Alternatively, in Figure 8B, by using a member which is radially constrained (such as a metallic disk for example) the application of generally radial movement or force to the disk 80 generates generally axial movement at the centre of the disk.

It will be noted that the annulus of piezoelectric material may be replaced by a plurality of strips of piezoelectric material in the form of, for example, a cross (this is described in more detail below).

Figure 9 shows a mount of similar form to that of Figures 6 and 7 but using an arrangement of the form shown in Figure 8B to generate the contra-vibrations.

In this case, the second filler canal 76' is formed in the centre of the lower dividing wall 72'. Movement of the dividing wall 72' moves the mass of fluid within the amplification chamber 60' giving the same effect as described above in connection with the other engine

mounts. This solution uses the piezo-hydraulic amplifier and the mechanical amplifier shown in Figure 3.

With reference to Figure 10, the mounts described above have in common that piezoelectric material is used to move a mass of fluid. The movement of the piezoelectric elements depends on the particular construction. One option as shown in the mounts above is to have an annulus of ceramic piezoelectric material of small thickness and to apply a field to either generate a generally radial or a generally axial change in dimension of piezoelectric material.

A second option is to have a pile of piezoelectric elements (for example, three) mounted on top of one another. The effect of this is to produce a series amplification of the effect. The total deformation of the pile of piezoelectric elements relative to the voltage applied is equal to the sum of the deformation of each of the piezoelectric strips. Thus, amplification of the deformation occurs. The total deformation is dependent on the level of electric field applied. However this solution is expensive.

A third solution is to use a bimorph piezoelectric material which has layers which act by bending when an electrical field is applied to the material. This type of material may be used to replace the piezoelectric elements 74' and the disk 75.

Figure 10 shows such a material in which the two layers are polarized in opposite

directions. In this case, the material flexes and causes the distal end of the material to move vertically in the direction X_r.

Figure 11 shows an alternative configuration in which two portions of the material of the type used in Figure 10 are joined end to end with different polarization directions. The result of this is that when a field is applied the element takes on an "S" shape which allows linear vertical displacement of the distal end of the element to occur. This helps with sealing between the element and the item to be displaced.

With reference to Figures 12A and 12B, another alternative is to form the bimorph strips into a cross. When the elements 78 are energised movement in the direction of arrow A is generated.

To conserve the rotational symmetry of the engine mount it is possible to use a bimorph piezoelectric element mounted as an annulus as shown in Figure 13. A full annulus is stiffer than the simple approximation to annulus shown in Figures 12A and 12B and thus the first resonant frequency is higher than that of the simple arrangement of Figures 12A and 12B. This arrangement can be placed in an engine mount instead of the piezoelectric element 74' and the disk 75 of Figure 9, for example.

CLAIMS

1. A resilient mount for resiliently supporting a member on a body, comprising body fixing means for fixing the mount to the body, member fixing means for fixing the mount to the member, resilient interconnection means resiliently interconnecting the body fixing means and the member fixing means for flexing in response to vibration of the member relative to the body, the resilient interconnection means at least partially defining a fluid-filled working chamber, the mount further including an amplification chamber and a quantity of piezoelectric material operable to control the volume of the amplification chamber and electrical control means coupled to the piezoelectric material and arranged to cause the piezoelectric material to control the volume of the amplification chamber in relation to the frequency of the said vibration and thereby to generate a force between the body fixing means and the member fixing means.

2. A resilient mount according to claim 1 wherein the compensation chamber is formed externally of the engine mount.

3. A resilient mount according to claim 1 or claim 2, wherein the piezoelectric material acts on the fluid in the amplification chamber via a surface of a first area, wherein the fluid in the amplification chamber acts on a wall of the working chamber having a second area and wherein the first area is greater than the second area.

4. A resilient mount according to any preceding claim, including dissipating means operable to dissipate electrical energy generated by the material in response to the vibration whereby the vibration.

5. A resilient mount according to claim 3, wherein the dissipating means is arranged

to operate at a predetermined range of frequencies of generated electrical energy whereby damping of the vibration occurs at a predetermined range of frequencies of the vibration.

6. A resilient mount according to any preceding claim, including a conduit interconnecting the chambers wherein the canal is supported on the mount by the quantity of piezoelectric material.

7. A resilient mount according to any preceding claim, wherein the member is a vehicle engine and the body is a vehicle body.

8. A resilient mount according to any preceding claim, wherein the piezoelectric material is a bimorph piezoelectric material.

9. A damper for damping a vibrating object comprising a damping mass, fixing means for fixing the damper to the vibrating object and a quantity of piezoelectric material arranged to couple the damping mass to the fixing means.

10. A damper according to claim 9, including control means electrically coupled to the quantity of piezoelectric material and operable to generate electrical control signals to cause the damping mass to be moved by the quantity of piezoelectric material in a predetermined direction and by a predetermined amount.

11. A damper according to claim 10, wherein the control means is arranged to cause movement of the damping mass generally in antiphase to the vibrations of the vibrating object.

12. A damper according to claim 10 or claim 11, wherein the control means is operable to cause the damping mass to move in a plurality of directions.

13. A damper comprising a damping mass, at least one piezoelectric element and a lever arrangement, the lever arrangement being arranged to transmit movement of the piezoelectric element to the mass and to increase the magnitude of the movement.

14. A hydroelastic engine mount constructed and arranged as described herein with reference to the drawings.

15. A damper constructed and arranged as described herein with reference to Figure 3 of the drawings.

Application No: GB 0002314.3
Claims searched: 1 to 8

Examiner: Colin Thompson
Date of search: 16 May 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): F2S (SAA)

Int Cl (Ed.7): F16F

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0464599 A1	(Metzeler Gimetall AG) See Fig 1	1,7
X	EP 0347666 A2	(Audi AG) See Fig 2	1
X	US 5738343 A	(Nakajima) Whole document relevant	1,7
X	US 5333455 A	(Yoshioka) Whole document relevant	1,7
X	JP 7158689 A	(Kurashiki Kako KK) See abstract	1
X	JP 5126200 A	(Mazda Motor Corp) See abstract	1,7

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